The Ionisation Produced by Hot Platinum in Different Gases.

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(Communicated by Professor J. J. Thomson, F.R.S. Received June 19,—Read June 28, 1906.)

(Abstract.)

The primary object of this investigation has been to try to discover the mechanism of the action by which the positive ions set free by hot bodies originate. It deals principally with measurements of the *steady* positive ionisation produced by hot platinum in various gases under different conditions.

In 1901* the writer showed that the negative ionisation from hot metals could be satisfactorily explained by supposing that it was caused by the freely moving corpuscles inside the metal escaping from the surface when their kinetic energy exceeded a certain value. In the present paper reasons are assigned for believing that a view of this kind will not account for the origin of the positive ions, which seem to be liberated by an action in which the atoms of the gas play a direct part. In the cases of steady ionisation here investigated it seems probable that it is not so much the external gas as that adsorbed by the metal which is effective.

It has been known for a long time that when a wire is heated for the first time it furnishes a very copious emission of positive ions. This effect has been examined previously in some detail by the writer,† who showed that it was very noticeable in a good vacuum and that the ionisation decayed asymptotically with time to a very small value. More recently the writer‡ has succeeded in showing that the reduced value of the leak thus obtained could be increased by the admission of small quantities of air. Further investigation has shown that there is a portion of the positive ionisation which is a function of the pressure of the external gas. It is with this part of the ionisation that the present paper chiefly deals.

Although the ionisation of this type is well marked and definite, its value even at atmospheric pressure is small compared with the initial value of the leak from a new wire.

The experimental methods employed are similar to those previously made

* 'Camb. Phil. Soc. Proc.,' vol. 11, p. 286; *cf.* also 'Phil. Trans.,' A, vol. 201, p. 473.

† 'Phil. Mag.' [6], vol. 6, p. 80.

‡ 'Camb. Phil. Soc. Proc.,' vol. 13, p. 58.

use of by the writer. Any important deviations from earlier methods are described in the paper. The investigation is more complete in the case of oxygen than of the other gases investigated, because: (1) oxygen was found to have a considerably greater effect on the ionisation, especially at low pressures; and (2) it is a simple elementary gas, which is easily prepared in a state of considerable purity.

Besides oxygen the paper contains an account of measurements of the ionisation of both signs from hot platinum in air, nitrogen, helium, and hydrogen. There are also measurements of the ionisation from a platinum surface in air when a calculable quantity of hydrogen is diffusing out from the interior of the platinum. The last-named experiments shed a considerable amount of light on the mechanism of the processes by which both the positive and negative ions are produced.

It has been found convenient to subdivide the paper according to the following scheme:—

The following is a brief account of the chief results of the investigation:—

The positive ionisation, *i.e.*, the number of positive ions produced by 1 sq. cm. of platinum surface per second, possesses a minimum value, which depends on temperature and pressure, in most gases. The positive ionisation in oxygen at a low pressure (less than 1 mm.) is much greater than in the other gases tried. In oxygen, at low pressures and temperatures below 1000° C., the ionisation varies as the square root of the pressure; at higher

temperatures and low pressures it varies nearly directly as the pressure; whilst at higher pressures at all temperatures the variation with pressure is slower, so that at pressures approaching atmospheric the ionisation becomes practically independent of the pressure.

The variation with pressure in air is similar to that in oxygen. In nitrogen and hydrogen the ionisation appeared to increase more rapidly with the pressure at high pressures than in oxygen. In very pure helium at low pressures there was a positive ionisation which was a function of the pressure.

The experiments on ionisation by collisions indicate that the positive ions liberated by hot platinum in oxygen are of the same order of magnitude as those set free by the collisions. They are not great masses approximating to dust particles.

The positive leak in oxygen always oscillated around a certain value under specified conditions. It was, therefore, never steady, so the minimum values were taken. This variability was much less marked, if it occurred at all, in the other gases.

The minimum value of the positive ionisation was found to remain practically constant with a wire heated during three months at various times (for 150 hours altogether) in oxygen at 900°—1000° C. Moreover, four different wires of different dimensions after continued heating in oxygen gave nearly the same value for the ionisation at the same temperatures and pressures.

The positive ionisation in air at constant temperature is smaller than that which would be obtained if the nitrogen were withdrawn, so as to leave only oxygen at a low pressure. The nitrogen, therefore, exerts an inhibiting effect on the oxygen.

The minimum value of the positive ionisation at a definite pressure in all gases appears to be connected with the temperature by the relation first deduced by the author for the negative ionisation. This relation may be written $i = A\theta^{\frac{1}{2}}e^{-Q/2\theta}$, where i is the ionisation, θ is the absolute temperature and A and Q are constants. The value of the constant Q, which is a measure of the energy associated with the liberation of an ion, is in most cases smaller for the positive than for the negative ionisation.

These results refer to wires which have been heated in a vacuum, and subsequently in the gas considered, for a long time. New wires exhibit peculiar properties, especially in regard to their behaviour under different electromotive forces. Old wires also exhibit hysteretic effects with change of pressure.

The view is developed that the positive ionisation is caused by the gas

adsorbed by the metal and the consequence examined of supposing the ionisation to be proportional to the amount of the adsorbed gas present. In the case of oxygen, by making the assumption that the rate of increase of the amount of the adsorbed gas is proportional jointly to the concentration of the external dissociated oxygen and to the area of "unoccupied" platinum surface, whilst the rate of breaking up is proportional to the amount present, a formula is obtained which agrees with the experimental results. This formula is that the ionisation $i = \mathrm{A}p/(\mathrm{B}+p)$, where $p = (k\mathrm{P}+\frac{1}{4}k^2)^{\frac{1}{2}}-\frac{1}{2}k$, P being the external pressure and k the dissociation constant of oxygen; A, B and k are constants depending on the temperature and are of the general form $a\theta^{\frac{1}{2}}e^{-b/\theta}$. Thus this view accounts for both the temperature and pressure variation.

The positive ionisation from the outer surface of a hot platinum tube in air is increased when hydrogen is allowed to diffuse through from inside the apparatus. The increase in the ionisation is proportional at constant temperature to the quantity of hydrogen escaping from the surface in unit time. For different temperatures the effect produced by a given quantity of hydrogen is greater the higher the temperature.

The negative ionisation from hot platinum in air is unaltered when hydrogen is allowed to diffuse out through the platinum.

These results show that neither the negative nor the positive ionisations usually observed with hot platinum heated in air or oxygen are due to residual traces of absorbed hydrogen.

Careful measurements were made to see if the negative ionisation in oxygen at low pressures varried with the pressure of the oxygen at constant temperature. Although the addition of oxygen increased the positive leak by a factor of 10, the negative leak was constant within the experimental error, in agreement with the work of previous observers.

The negative ionisation was found to have very nearly the same absolute value and the same temperature variation for two wires of different dimensions when heated in oxygen.

A wire which has been heated in hydrogen furnishes a negative ionisation which is very big compared with that from a wire heated in oxygen at the same temperature. If the hydrogen is at a pressure of the order of 1 mm. the negative ionisation can be rapidly reduced to a much smaller value by applying a high negative potential to the wire. The wire subsequently recovers its ionising power if the potential is reduced again. Under these conditions the ionisation varies in an interesting way with the time. The reduction in the ionising power of the wire appears to be caused by the bombardment of the surface by positive ions produced by collisions.

When a platinum wire, which has previously been allowed to absorb

hydrogen, is heated for a long time in a good vacuum so as to expel the gas, its ionising power does not appear to be reduced. The ionisation apparently is not a definite function of the quantity of gas absorbed by the wire. The amount of hydrogen which a platinum wire will absorb at a low pressure is much greater than is usually suspected.

The results indicate that the increase in the negative ionisation is not caused by the hydrogen directly but rather by some change it produces in the surface of the platinum.

On the Electric Inductive Capacities of Dry Paper and of Solid Cellulose.

By Albert Campbell, B.A.

(Communicated by Dr. R. T. Glazebrook, F.R.S. Received June 12,—Read June 21, 1906.)

(From the National Physical Laboratory.)

Although dry paper is widely used as a supporting and insulating material in telephone cables, the published data with regard to its specific inductive capacity (or permittivity) appear to be very meagre. For this reason Mr. Gavey, C.B., Engineer-in-Chief of the Post Office, asked us to investigate the matter, and sent for test a large number of samples of paper obtained from four different cable manufacturers. All the samples consisted of what is known as "chemical wood paper," presumably free from lignified fibre. This type of paper, according to the Society of Arts Report on the Durability of Papers, is better in lasting quality than "mechanical wood paper" or paper made from straw, jute or esparto grass. Mr. Gavey, in addition, has kindly supplied the results of some tests on actual cables and further data for some of the samples of paper. This information is embodied in Part II of the present paper.

Part I.—Tests on Dry Paper.

One of the main difficulties in the testing of paper lies in the fact that it absorbs moisture so readily; and the presence of moisture has a large effect on the specific inductive capacity and an enormous effect on the insulation-resistance. The nature of these effects is well illustrated by the curve in fig. 6 (Part II, p. 204), which shows how the capacity increases and the resistance decreases as a well-dried cable is allowed to absorb moisture from the atmosphere.